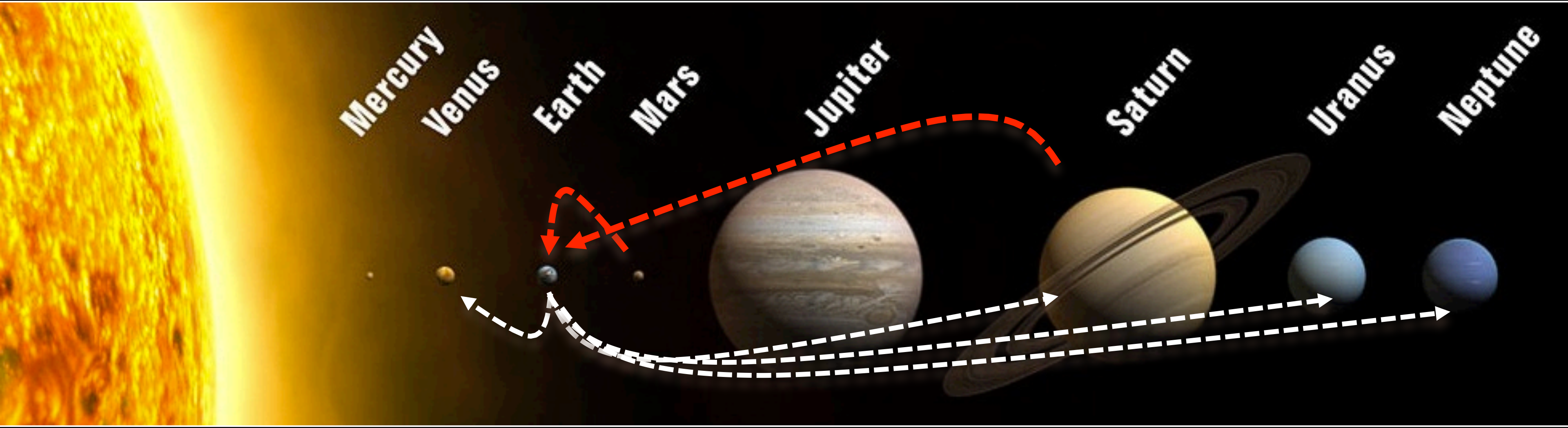
Heat Shield for Extreme Entry Environment Technology (HEEET) for Near-Term Robotic Science Missions and Longer-Term Human Missions



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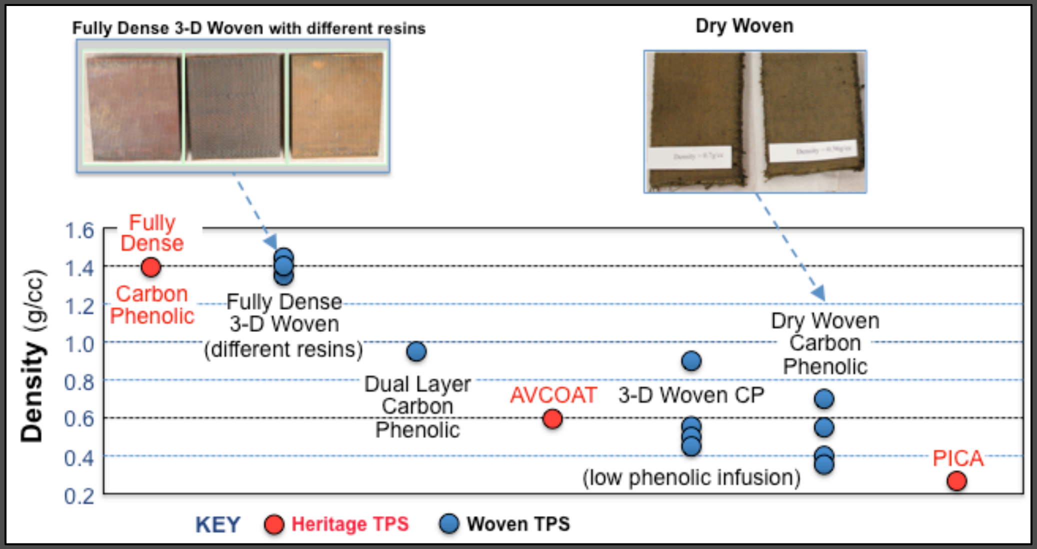
11th International Planetary Probe Workshop

June 20th, Pasadena, California

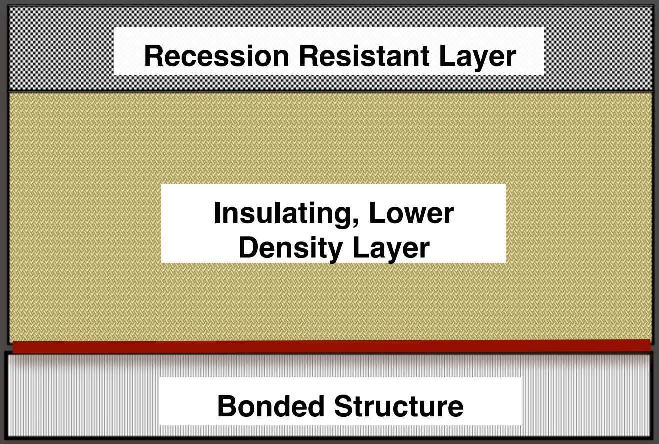
WOVEN TPS AND HEEET

Last year we reported, viability of the 3-D Woven TPS.

- 3-D Woven TPS, not a single system but a family :
  - *Woven TPS: An approach to the design and manufacturing of ablative TPS by the combination of 3-D weaving that allows precise placement of fibers in an optimized manner and resin infusion if needed*
  - Explored the "10,000" manufacturing ways of formulating a TPS
  - Ablative TPS options, dry-woven as well as resin infused systems, ranged in density from (0.3 g/cc – 1.4 g/cc) in overall density
  - Highlighted the Woven TPS potential for extreme entry and decided on the two layer system



HEEET Architecture



BACKGROUND: A DECADE TO MAKE THE CASE

- (1997-2002) MSR required extremely reliable heat-shield
  - Heritage Carbon Phenolic based on Galileo/P-V
- Made the case difficult or impossible for mission proposers
  - New Frontier AO (2004) and (2008)
  - Discovery (2006, 2010)
- Carbon Phenolic Workshops I (2010)
  - SOA Assessment
- Carbon Phenolic Workshop II (2012)
  - Alternate to Heritage Carbon Phenolic
- Four White Papers submitted to the NRC Decadal Survey (2009)
  - NASA needs to revive alternate to HCP or find alternate solutions

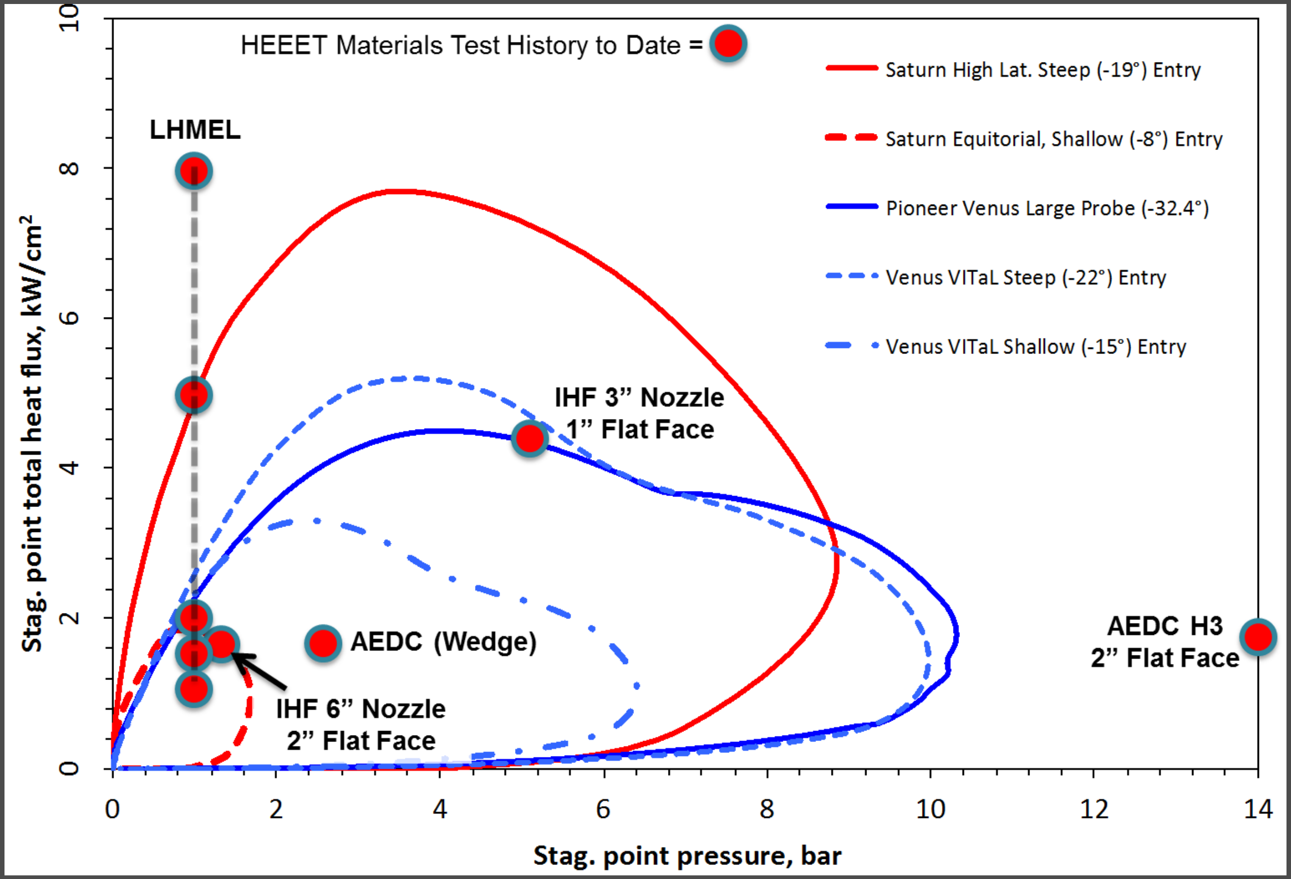
Missions to Venus, Outer Planets and Sample Return Missions are impacted by NASA's inability to maintain or invest in ablative TPS for Extreme Entry Environments or for missions that require very high reliability.

HEAT-SHIELD FOR EXTREME ENTRY ENVIRONMENT TECHNOLOGY (HEEET)

- *This year NASA (STMD and SMD Mission Directorates) committed to developing and providing HEEET as a Government Furnished Equipment (GFE) for the upcoming Discovery proposers.*
  - *The HEEET Team is committed to delivering the Technology by 2017*
- *Highlight the accomplishments to-date and very briefly describe the challenges*

ARC JET TESTS

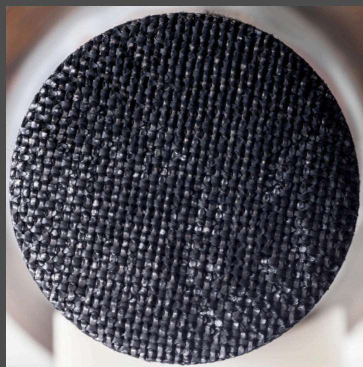
HEEET Materials Test History to Date =



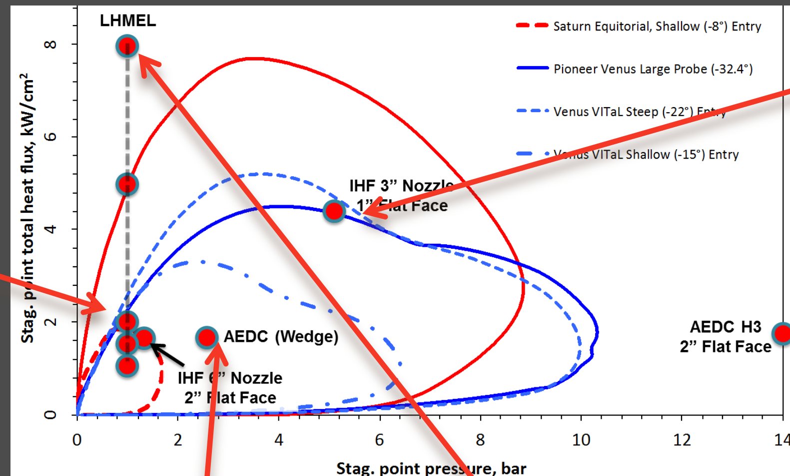
Testing to-date across a number of facilities and test conditions

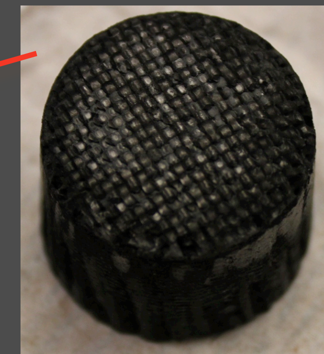
- Resulting in high confidence in the inherent Robustness of the material
- No readily apparent failure were observed in any of these tests

ARC JET TEST RESULTS – TWO LAYER SYSTEM

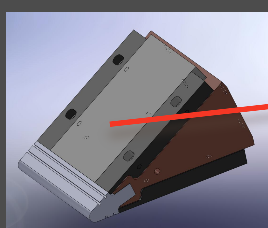


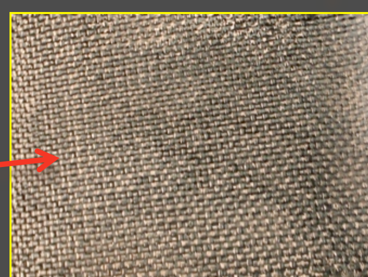
IHF 6” Nozzle
(1700 W/cm2, 1.3 atm)



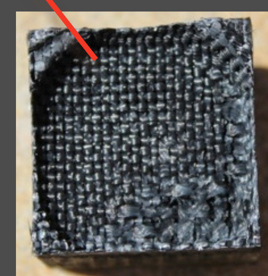


IHF 3” Nozzle
(4800 W/cm2, 6 atm)

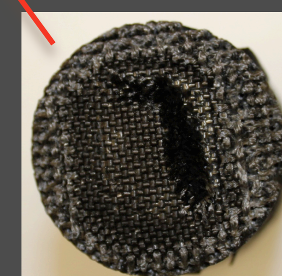




AEDC Wedge
1650 W/cm2, 2.6atm. High shear



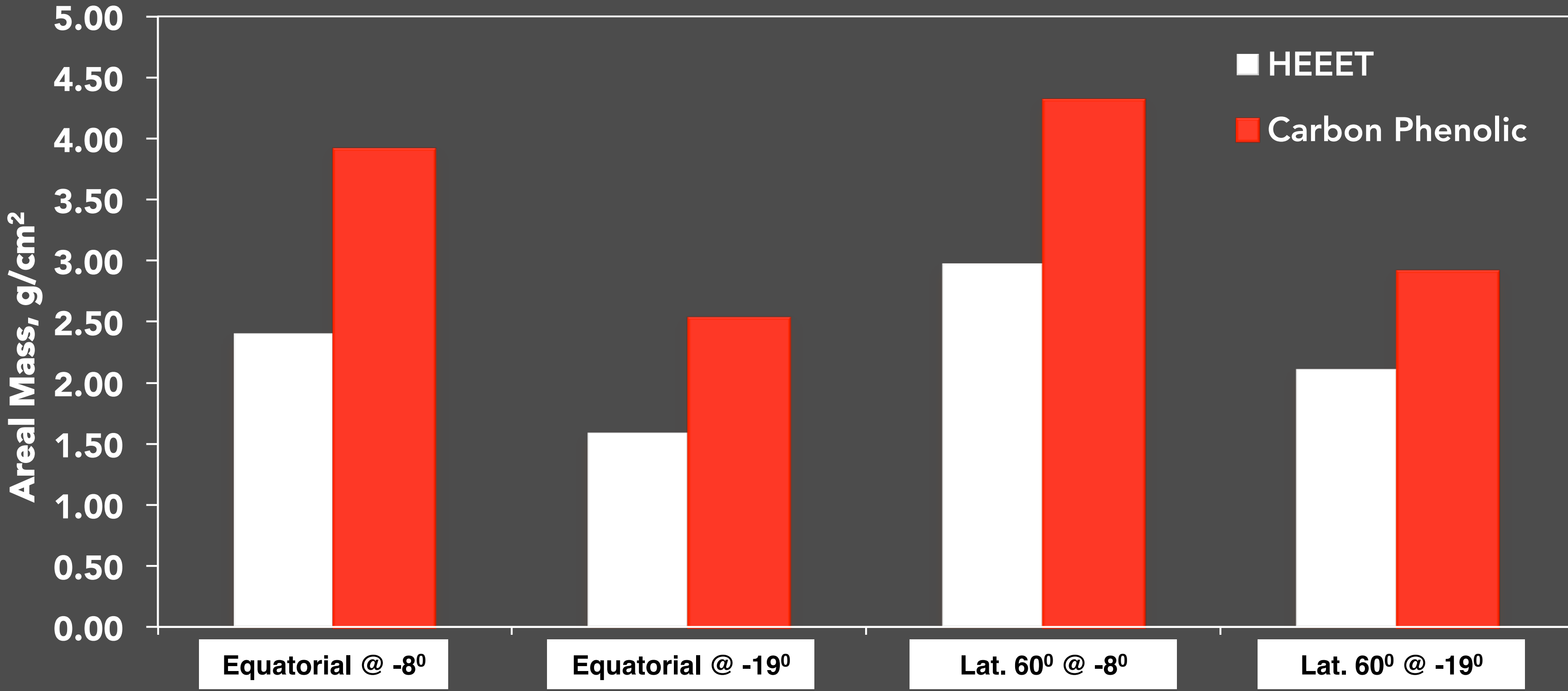
LHEML
(8000 W/cm2, 1 atm)



AEDC
(14 atm.1850 W/cm^2)

- No failure observed in HEEET acreage material to-date.
  - Preliminary seam testing shows promising results
  - In some tests, Chop Molded and Tape Wrapped Carbon Phenolic show failure modes

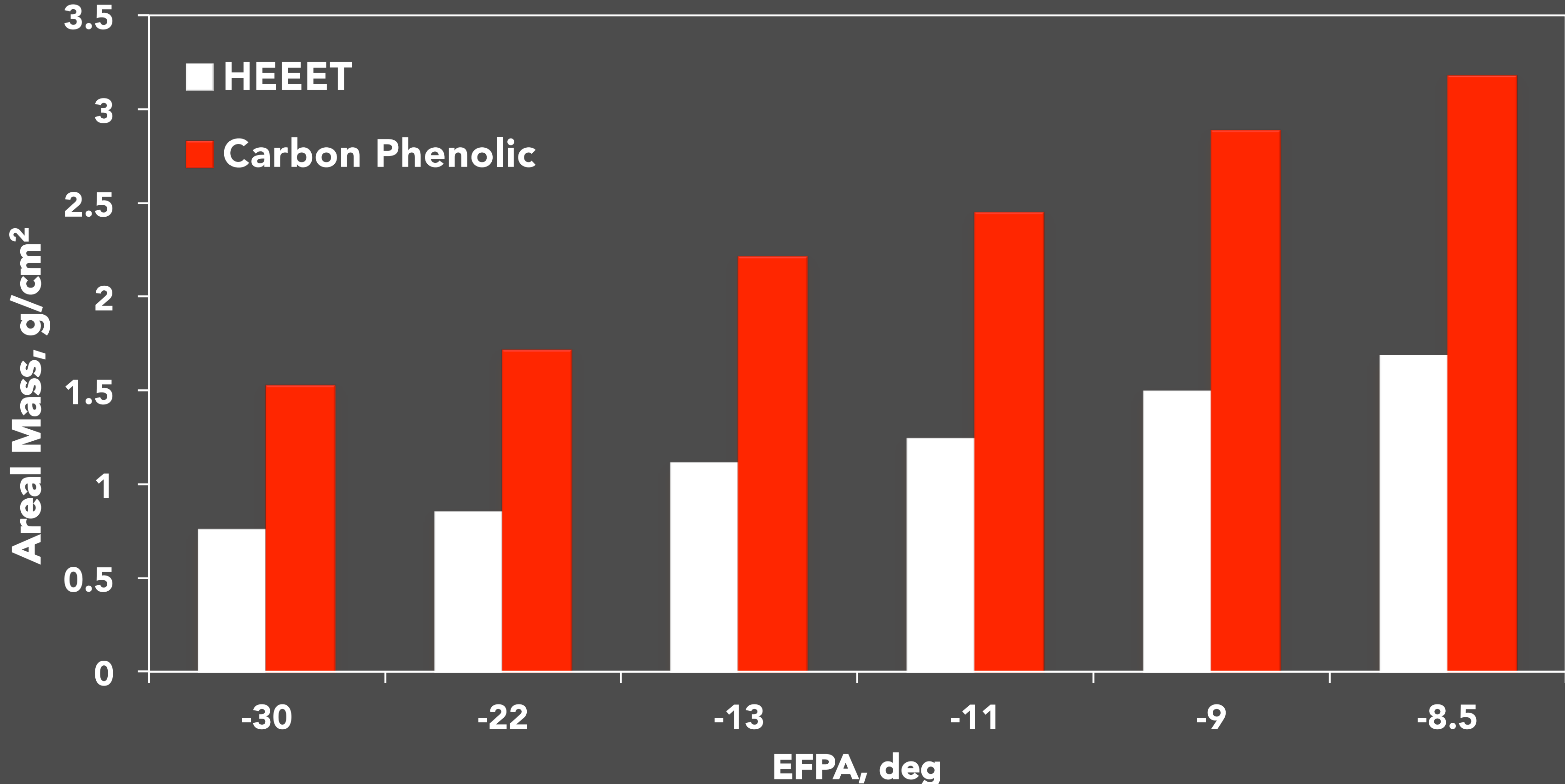
SATURN PROBE AREAL MASS COMPARISONS



- Areal mass of the 2-layer system has the potential for ~ 40% mass savings compared to that of heritage Carbon Phenolic
  - Un-margined; preliminary estimate with very limited property data
  - Carbon Phenolic heat-shield mass estimates ~ 50% of the entry mass

Performance combined with robustness makes HEEET an exceptional TPS

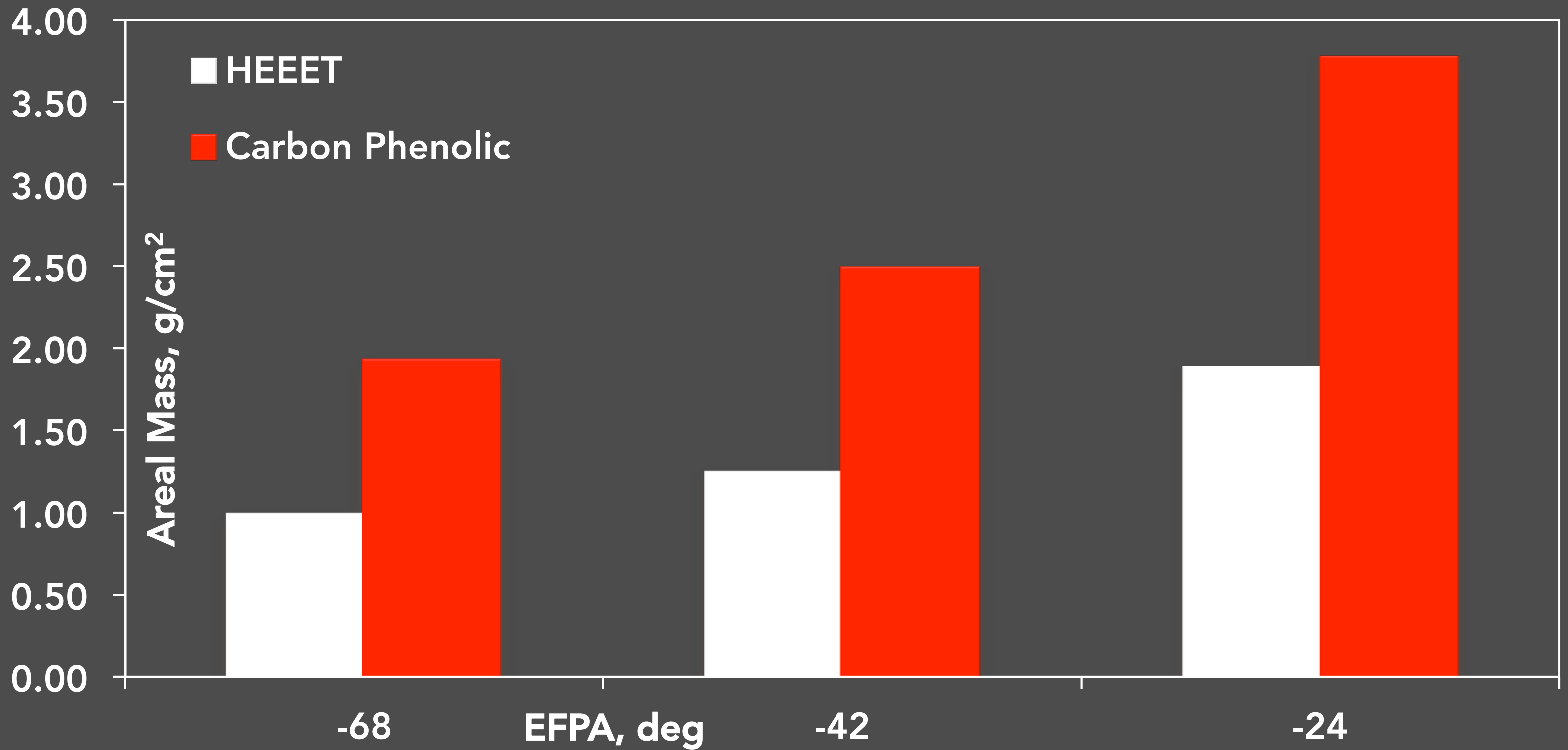
VENUS (10.8 KM/S)
AREAL MASS COMPARISON



- Areal mass of the HEEET is potentially as low as ~ 50% of the Carbon Phenolic for a broad range of entry trajectories
  - HEEET sizing utilized preliminary thermal response model, zero margin sizing for both materials

Performance combined with robustness makes HEEET an exceptional TPS

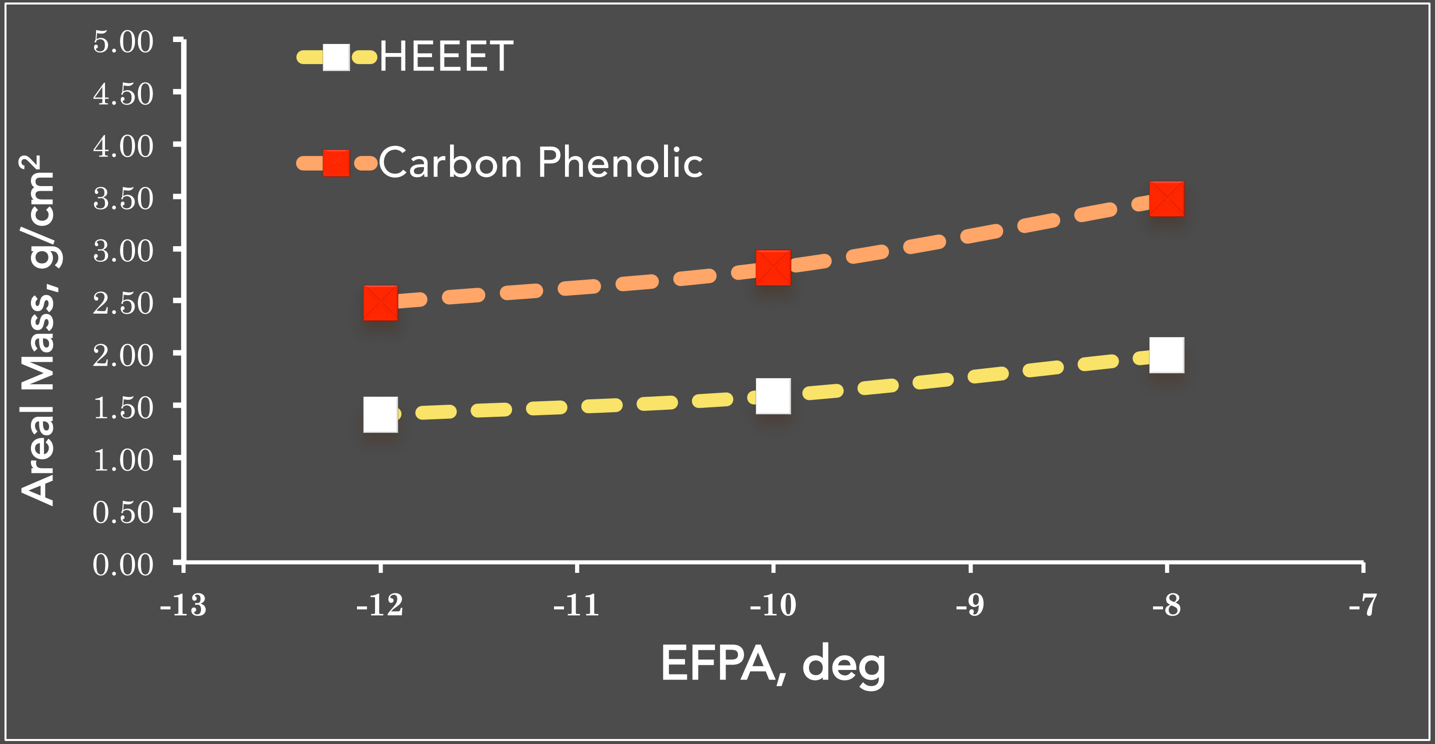
URANUS MISSION DESIGN
AREAL DENSITY COMPARISONS



- 2-layer system can result in potential ~ 50% mass savings compared to Carbon Phenolic for the range of entry configurations considered for Uranus small probe(s)
  - Un-margined and based on very limited property data
- Simulation on a flank location comparison is very similar in that the zero-margin areal density is ~ 50% as that of Carbon Phenolic

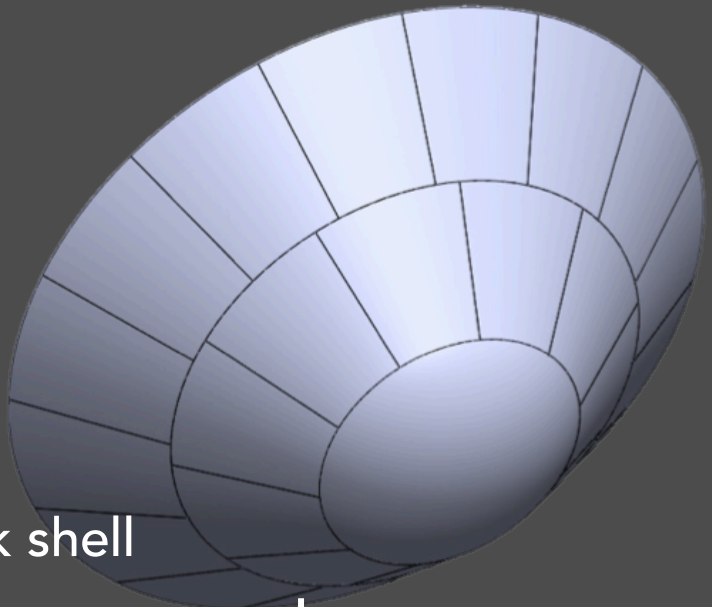
SAMPLE RETURN MISSION TRADE STUDIES
(V = 15 KM/S, M = 50 KG, DIA. = 0.8 M) :
TPS AREAL MASS AND THICKNESS

- 3-D WTPS allows larger entry corridor, robustness and mass efficiency
- Carbon Phenolic – mass inefficient especially at shallower EFPA



- Mass savings of ~40% over CP
  - Zero margin sizing, preliminary HEEET response model

TECHNOLOGY MATURATION CHALLENGES



- System/Manufacturing
  - Molding flat panels
  - Seams
  - Resin Infusion at scale
- Integration
  - Aeroshell sub-structure and with back shell
- Flight System design tools development and verification
  - Thermal response an example of design tool needed
  - Prototype Test Unit

Successful Prototype design, build and testing = TRL 6

CONCLUDING REMARKS

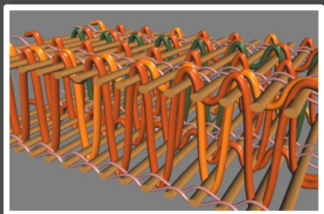
- HEEET team is committed to delivering a mature technology by 2017
  - Successful formulation activities (testing, system studies and planning) and community advocacy has resulted in mission infusion opportunities for upcoming Discovery and New Frontier
  - Challenges in maturing the technology need to be overcome and on-going studies and progress will be reported in the next IPPW

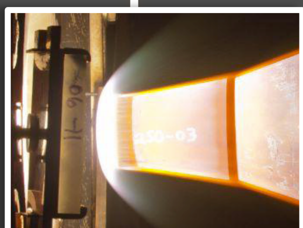
- In addition to technology maturation, HEEET team will support upcoming Discovery (2014) proposals and future New Frontier proposal efforts
  - Request for HEEET outside of US
  - If permitted HEEET can support international missions

ACKNOWLEDGEMENTS

- Support and commitment of STMD, GCDP within STMD and SMD-PSD allowed us to mature our plans in FY’13. We are very grateful.
- Decision by STMD and SMD to identify HEEET as a high priority technology and define HEEET as a GFE so the proposing teams to Discovery 2014 AO do not have to be concerned about the risk associate with maturing technology.
- We are grateful to OPAG and VEXAG for identifying HEEET as a high priority and highlighting in their recommendations to SMD-PSD
- The work done by SMD-ISPT-EVT project in defining the entry environment for Venus, Saturn and Uranus were used in our sizing studies.
- This work is coordinated across and supported by personnel at multiple NASA centers (ARC, LaRC and JSC)
- Exceptional support and partnership by industrial partner Bally Ribbon Mills embarking on weave development activities continues to be critical to the success of Woven TPS efforts.

A BRIEF HISTORY WOVEN TPS TECHNOLOGY:
WOVEN TPS TECHNOLOGY MATURATION AND MISSION INSERTION

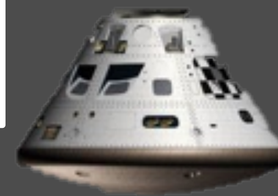




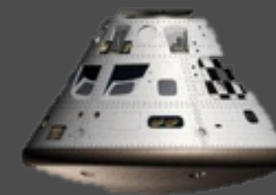
Woven TPS GCT BAA

3-D Woven Multifunctional Ablative TPS (3D-MAT)

Enabling Orion with Lunar Capable Compression Pad



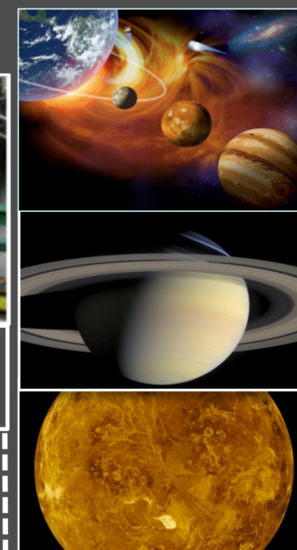
2017



2022+

Heat-shield for Extreme Entry Environment Technology (HEEET)

Tech. Maturation to enable Venus, Saturn and outer planets missions



2020 - 2022

Robust Heat-shield for Human Missions (Future Potential)

April 2011

Jan. 2012

June, 2012

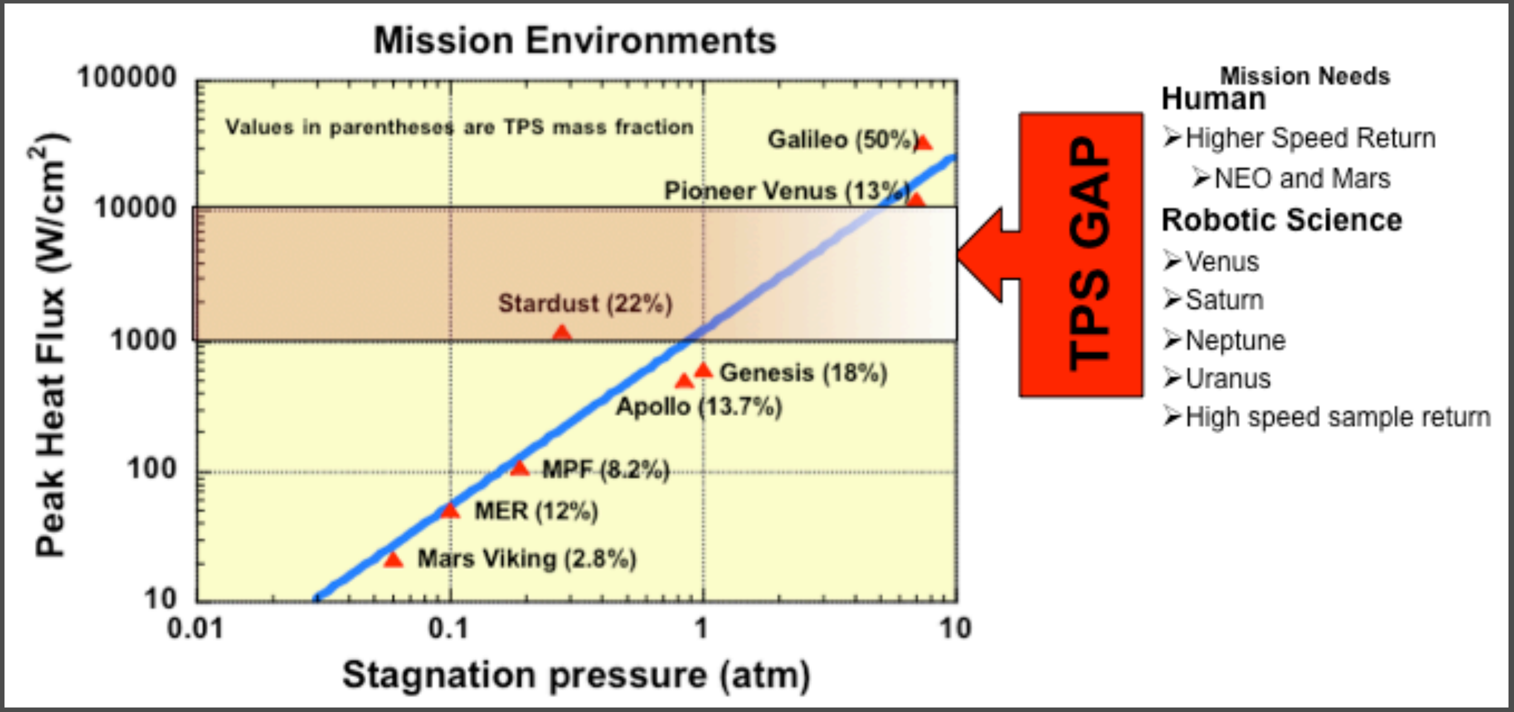
Oct, 2013

Sept. 2016

2016+

ENABLING MISSIONS IN THE COMING DECADES

- Decadal Survey Recommended Missions (NF) require:
  - Revival of heritage carbon phenolic (HCP), or
  - Development of advanced TPS that is superior in performance to HCP, as robust as HCP and sustainable in the longer term



Current ablative TPS State of the Art